THE PROOF IS IN THE DIRT: VERIFYING PAST EARTHQUAKES

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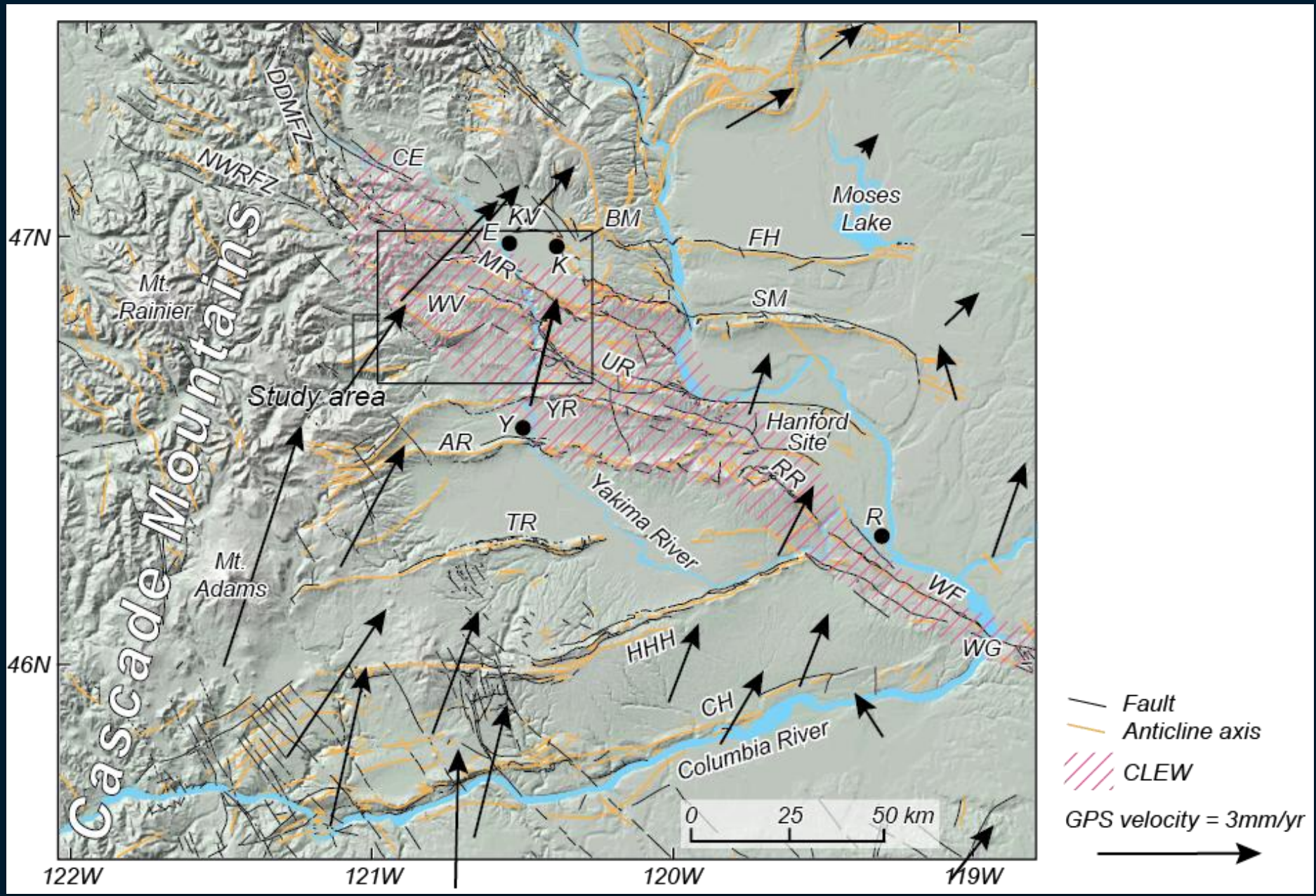
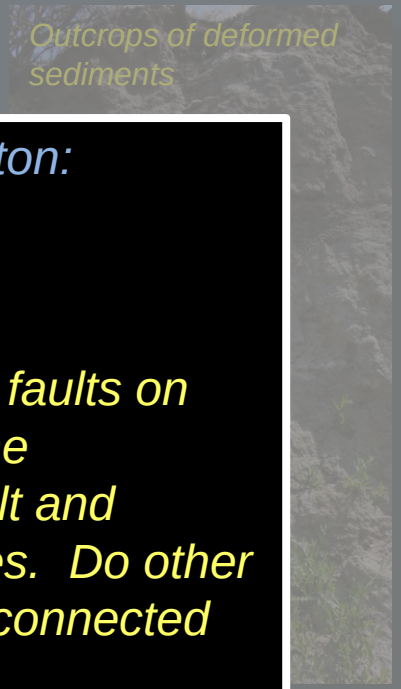
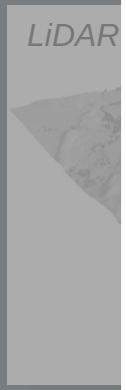

Cascade Mountains
DDMFZ
NWRFZ
CE
KV
BM
E
K
MR
WV
Mt. Rainier
Study area
UR
YR
Y
AR
Moses Lake
FH
SM
Hanford Site
RR
R
Yakima River
TR
Mt. Adams
WF
WG
HHH
CH
Columbia River
0
25
50 km
47N
46N
122W
121W
120W
119W
Fault
Anticline axis
CLEW
GPS velocity = 3mm/yr

Paleoseismology – study of past earthquakes using evidence from the geologic record (rocks, faults, etc.)

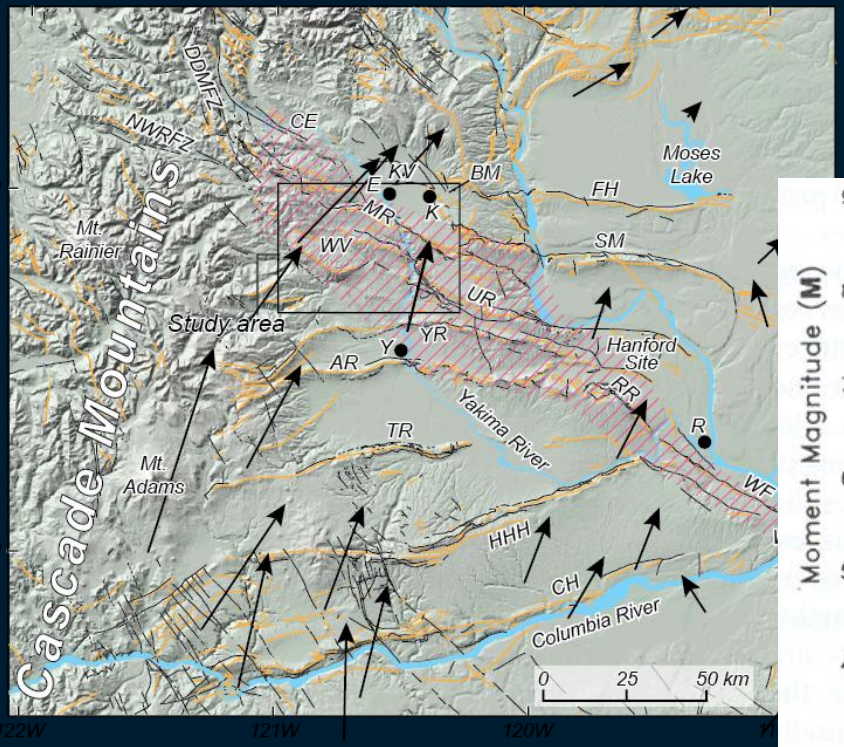


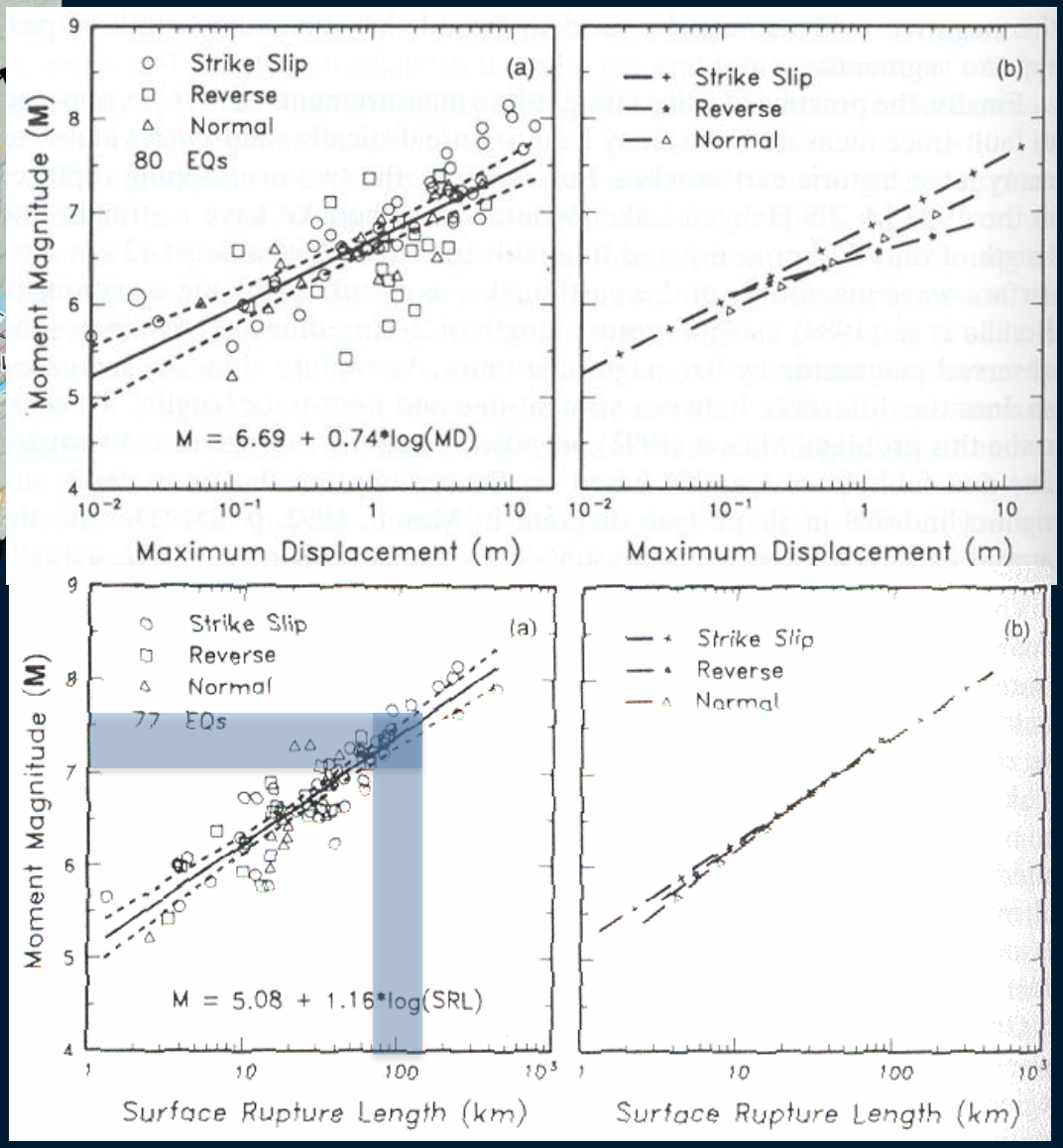


Motivations for studying paleoseismology in central Washington:

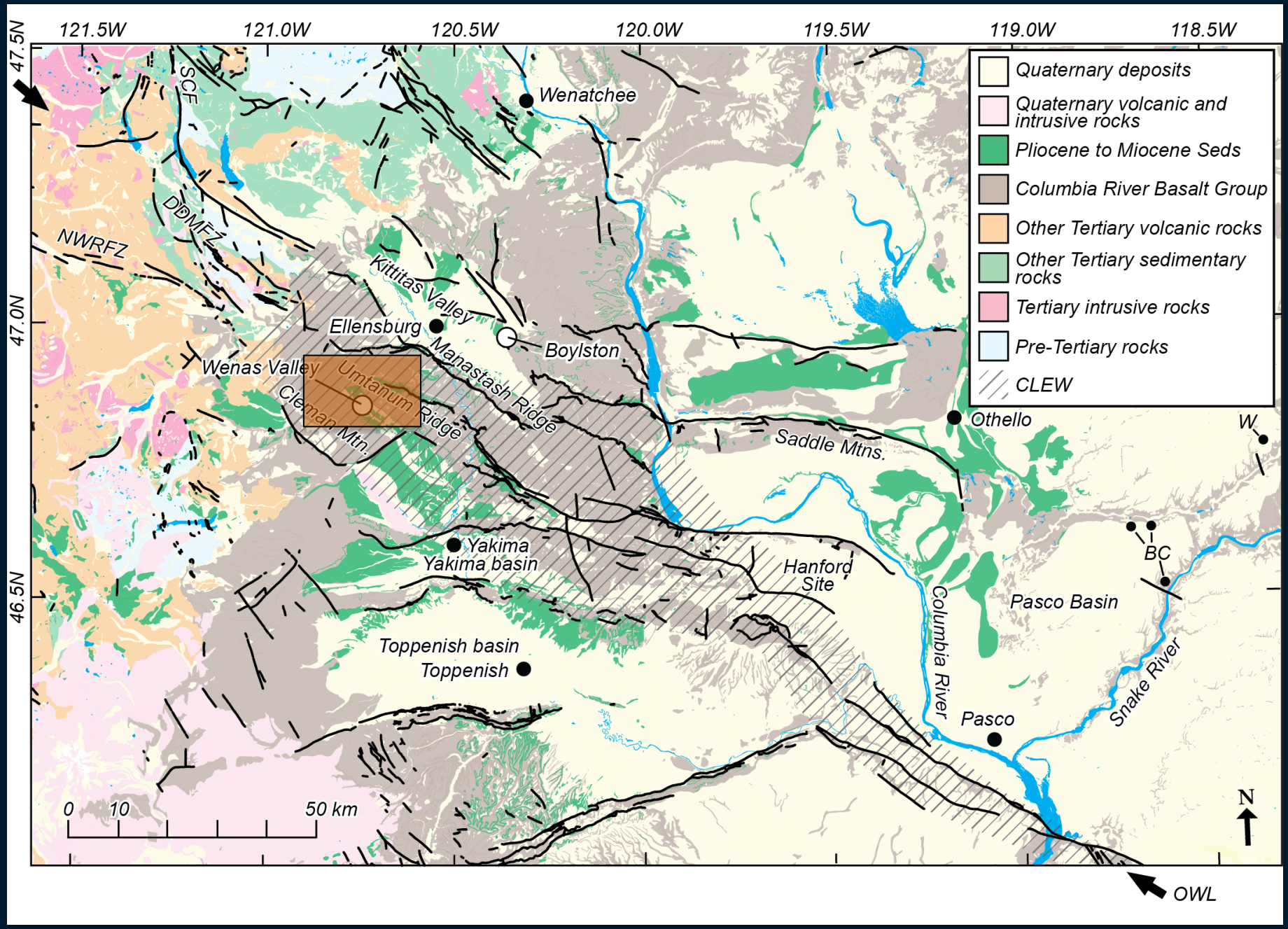
- *Landscape screams active tectonics.*
- *Cascade Mountains are usually considered a barrier – faults on the west are considered separate from faults east of the Cascades. Two faults – White River-Naches River fault and Darrington-Devils Mountain fault – cut across Cascades. Do other faults? Faults on the west side are active – if they are connected with the YFTB, your faults are too.*
- *Thin skin tectonics vs thick skinned tectonics – earlier hazard assessment assumed many of the folds in YFTB were thin skinned (not deeply rooted in crust) – and thus lacked seismic features like fault scarps from past earthquakes.*

Scarp
vertica
fault or by erosion.





YFTB structures fall in this range


121.5W
121.0W
120.5W
120.0W
119.5W
119.0W
118.5W
47.5N
47.0N
46.5N
SCF
DDMFZ
NWRFZ
Wenatchee
Kittitas Valley
Ellensburg
Boylston
Manastash Ridge
Wenas Valley
Umtanum Ridge
Cleman Mtn.
Saddle Mtns.
Othello
W
Yakima
Yakima basin
Hanford Site
BC
Pasco Basin
Columbia River
Snake River
Toppenish basin
Toppenish
Pasco
0
10
50 km
N
OWL
Quaternary deposits
Quaternary volcanic and intrusive rocks
Pliocene to Miocene Seds
Columbia River Basalt Group
Other Tertiary volcanic rocks
Other Tertiary sedimentary rocks
Tertiary intrusive rocks
Pre-Tertiary rocks
CLEW

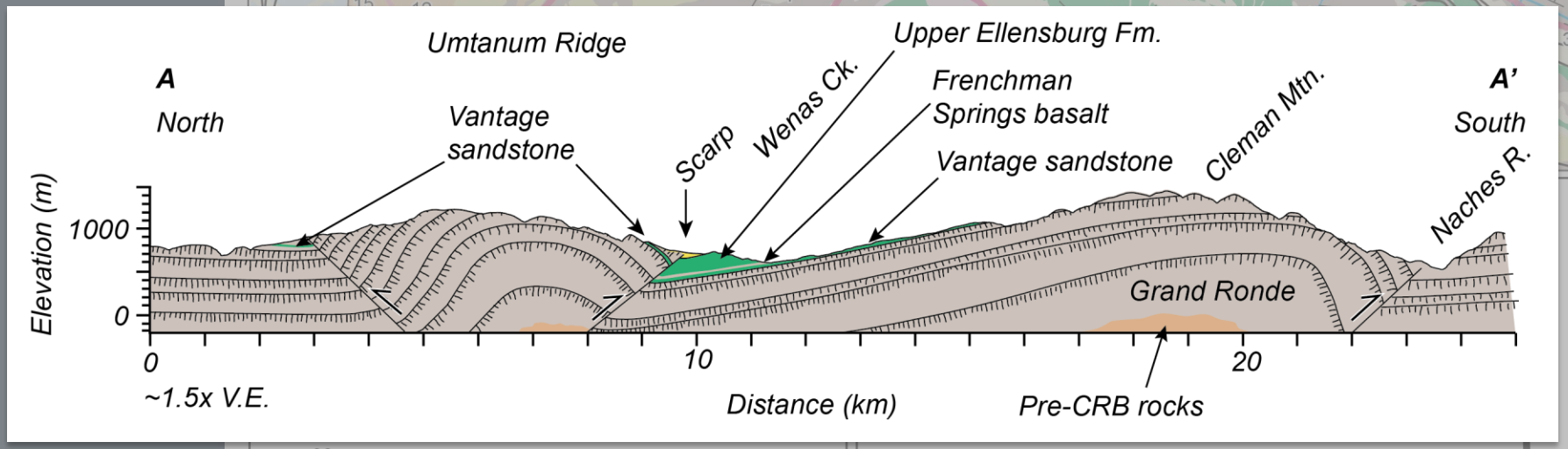

Umtanum Ridge
A
North
Vantage sandstone
Scarp
Wenas Ck.
Upper Ellensburg Fm.
Frenchman Springs basalt
Vantage sandstone
Cleman Mtn.
A'
South
Naches R.
Grand Ronde
Pre-CRB rocks
Elevation (m)
1000
0
0
10
20
~1.5x V.E.
Distance (km)


Image U.S. Geological Survey
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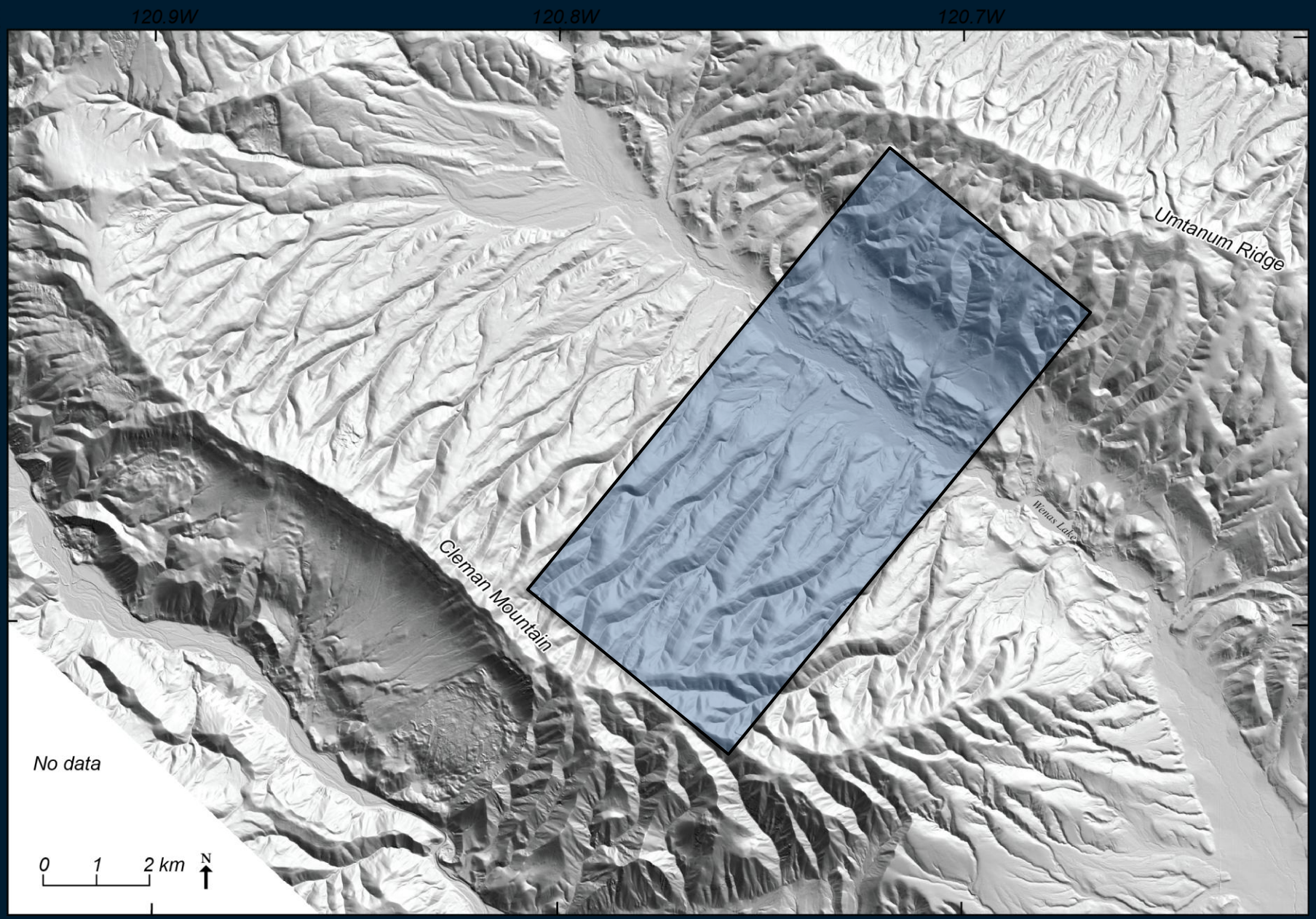
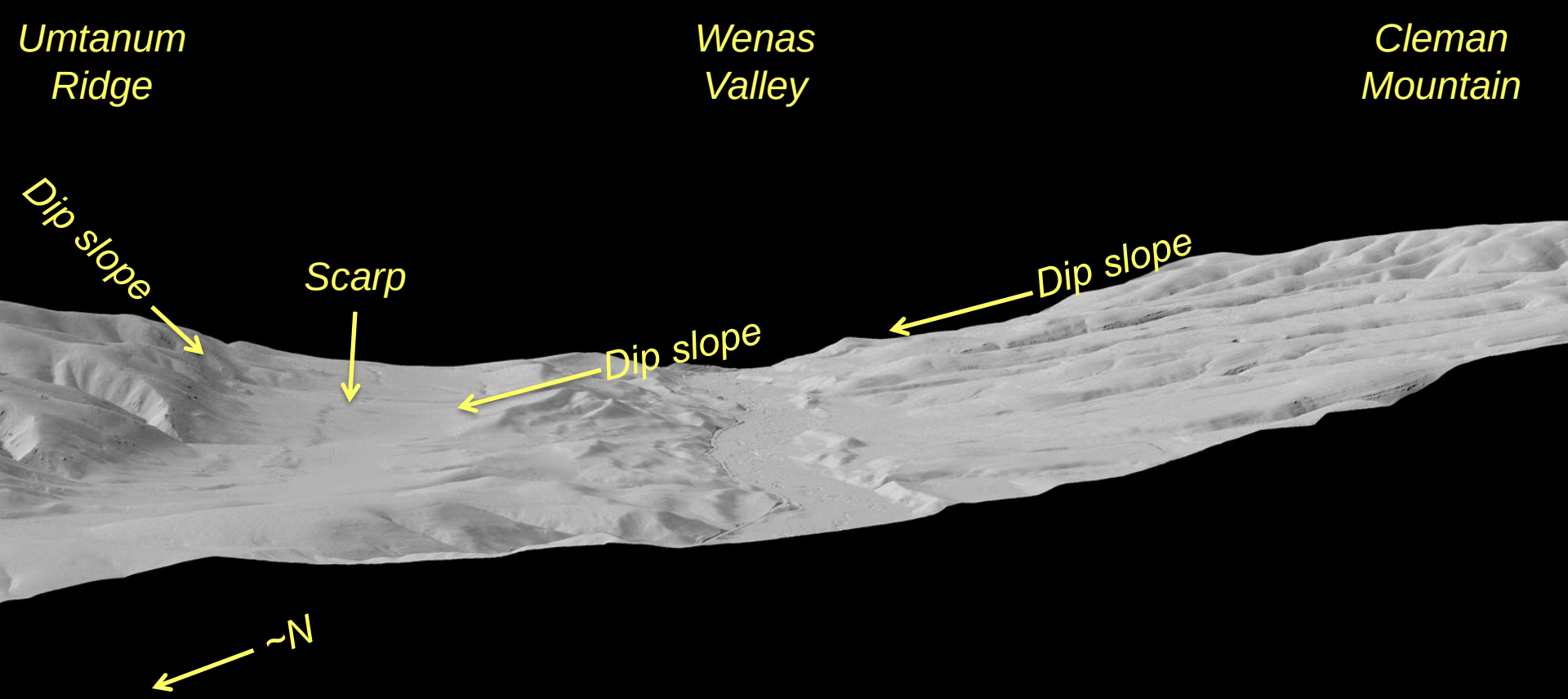

120.9W
120.8W
120.7W
46.9N
46.8N
Umtanum Ridge
Cleman Mountain
Wenas Lake
No data
0 1 2 km
N

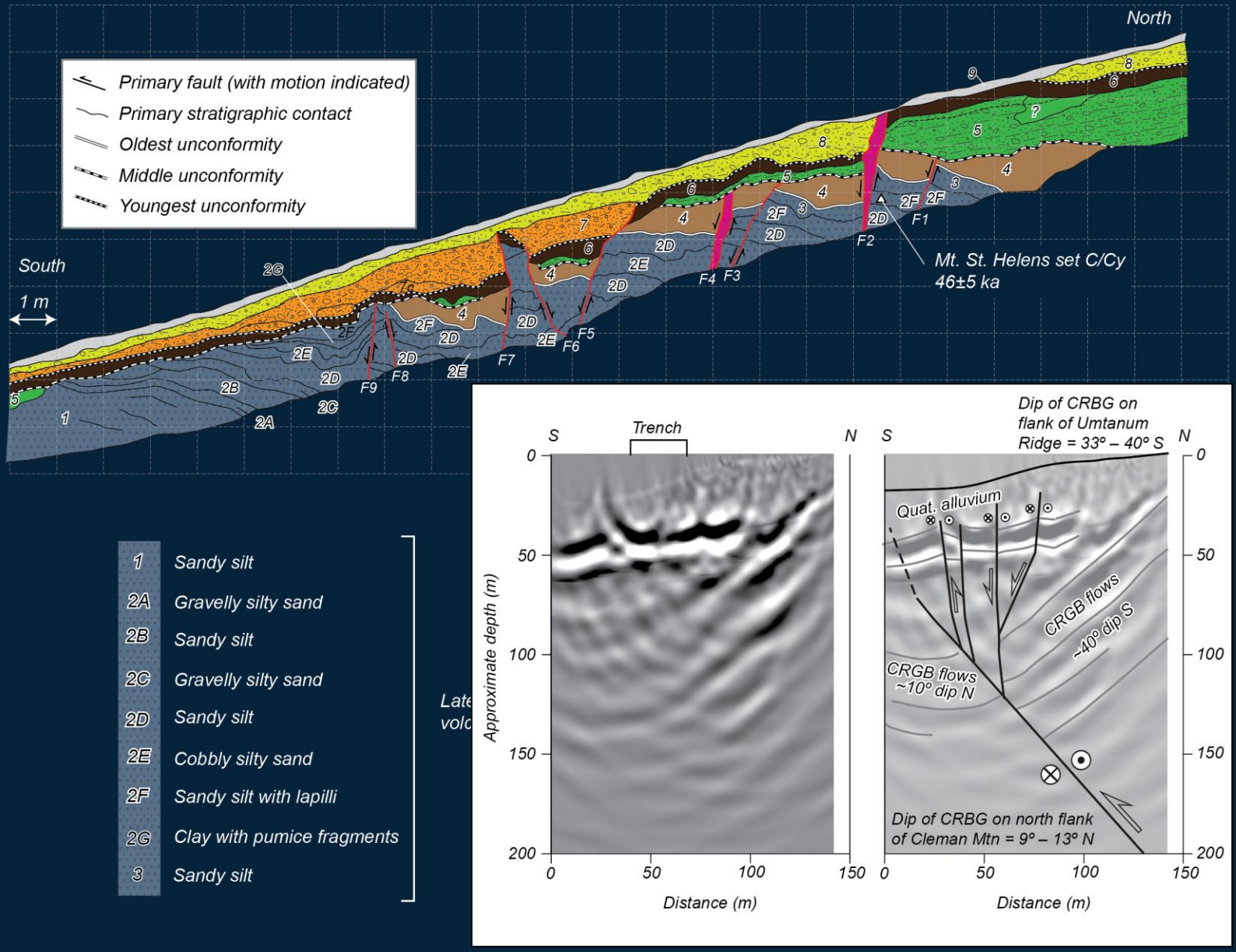
Oblique LiDAR image, Wenas Valley – Looking ~East



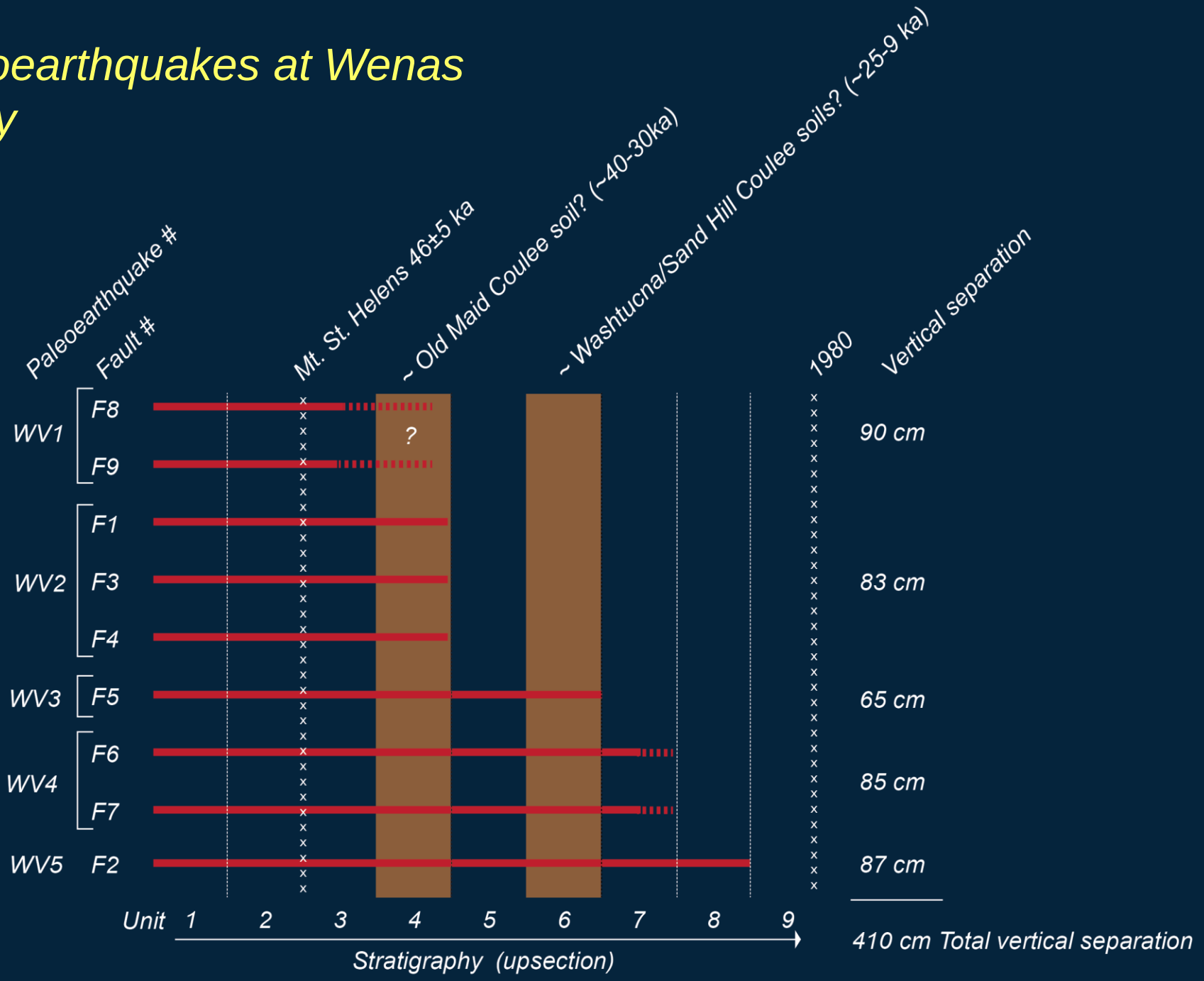

DEERE


DEERE

McCabe Place Trench Log -Wenas Valley, Umtanum Ridge

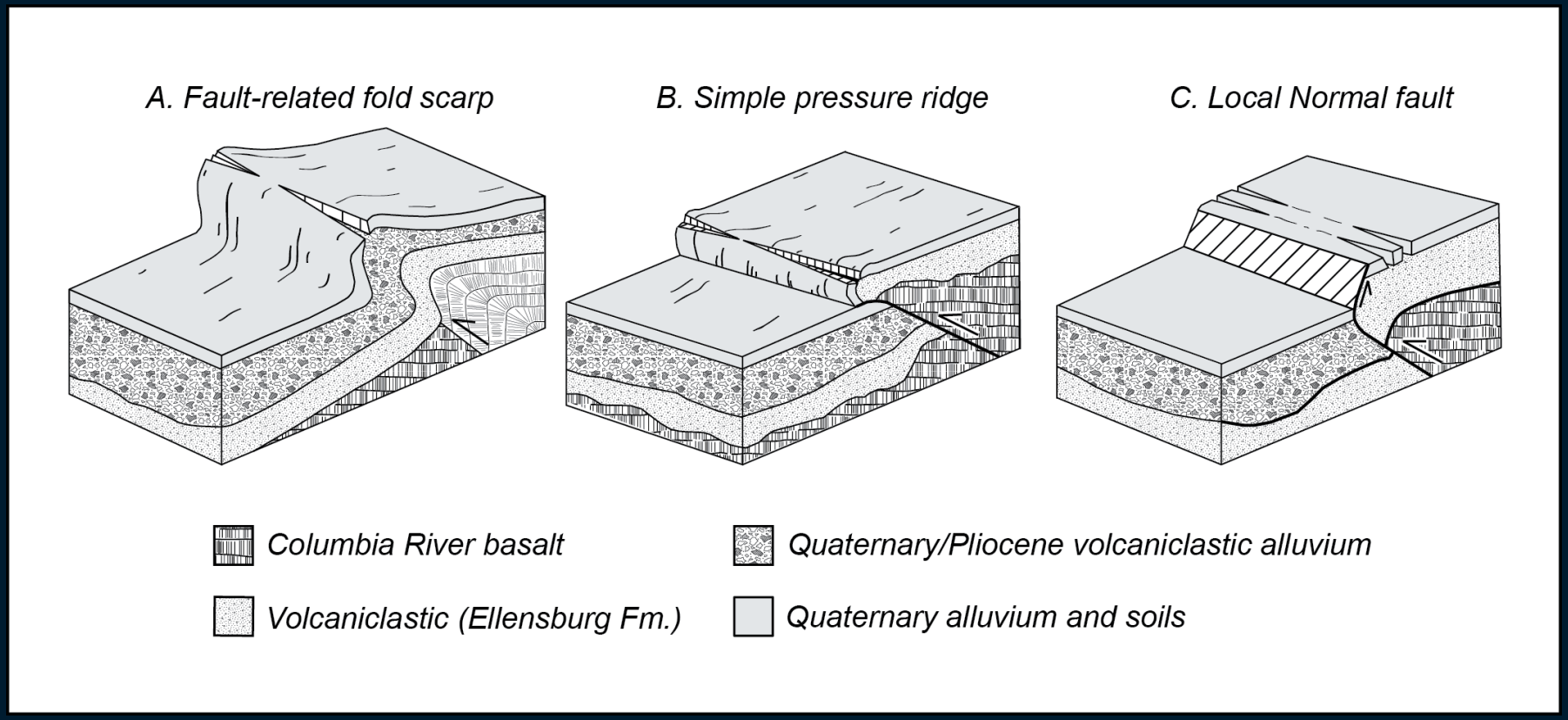


Paleoearthquakes at Wenas Valley

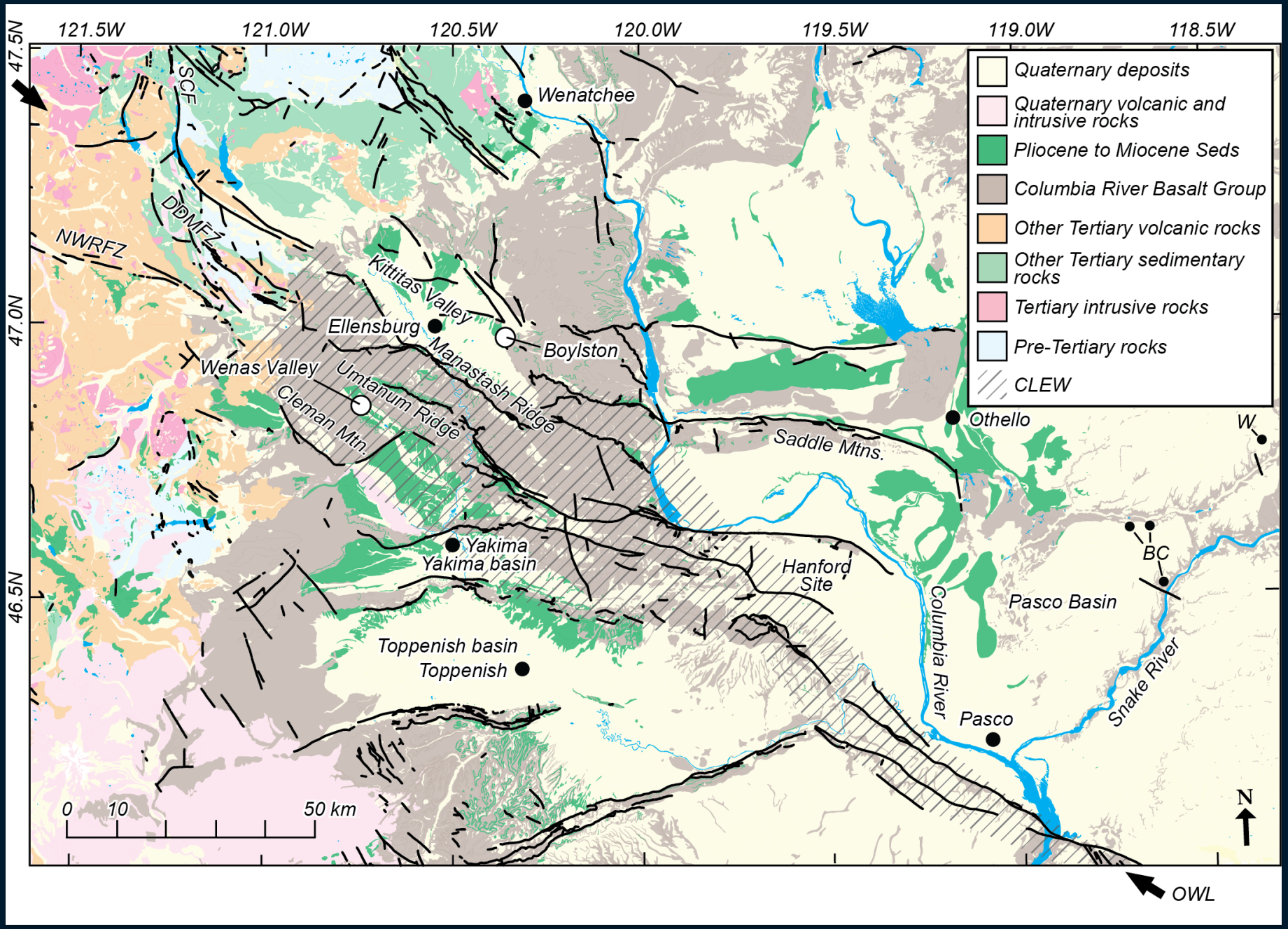


Why do we see normal faults at Wenas?
The master reverse fault is buried – we can see evidence for it in the seismic reflection survey.

Recent surface ruptures on reverse faults shed light on what happened at Wenas.



Examples from Yu et al, 2010, BSSA - 2008 M7.9 Wenchuan, China earthquake


121.5W
121.0W
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118.5W
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SCF
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Wenatchee
Kittitas Valley
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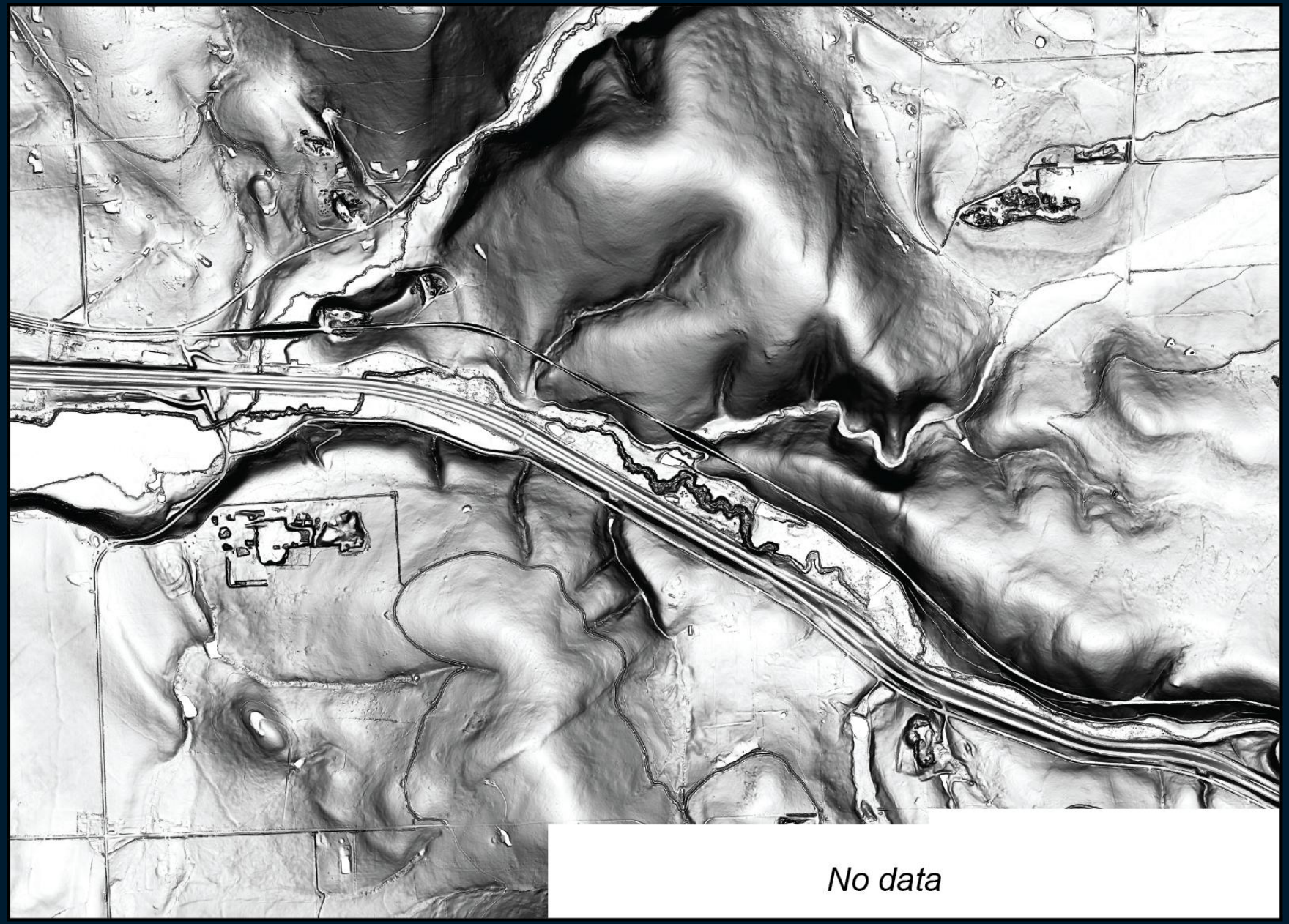
Boylston
Manastash Ridge
Wenas Valley
Umtanum Ridge
Cleman Mtn.
Saddle Mtns.
Othello
W
Yakima
Yakima basin
Hanford Site
BC
Pasco Basin
Columbia River
Snake River
Toppenish basin
Toppenish
Pasco
0
10
50 km
N
OWL
Quaternary deposits
Quaternary volcanic and intrusive rocks
Pliocene to Miocene Seds
Columbia River Basalt Group
Other Tertiary volcanic rocks
Other Tertiary sedimentary rocks
Tertiary intrusive rocks
Pre-Tertiary rocks
CLEW

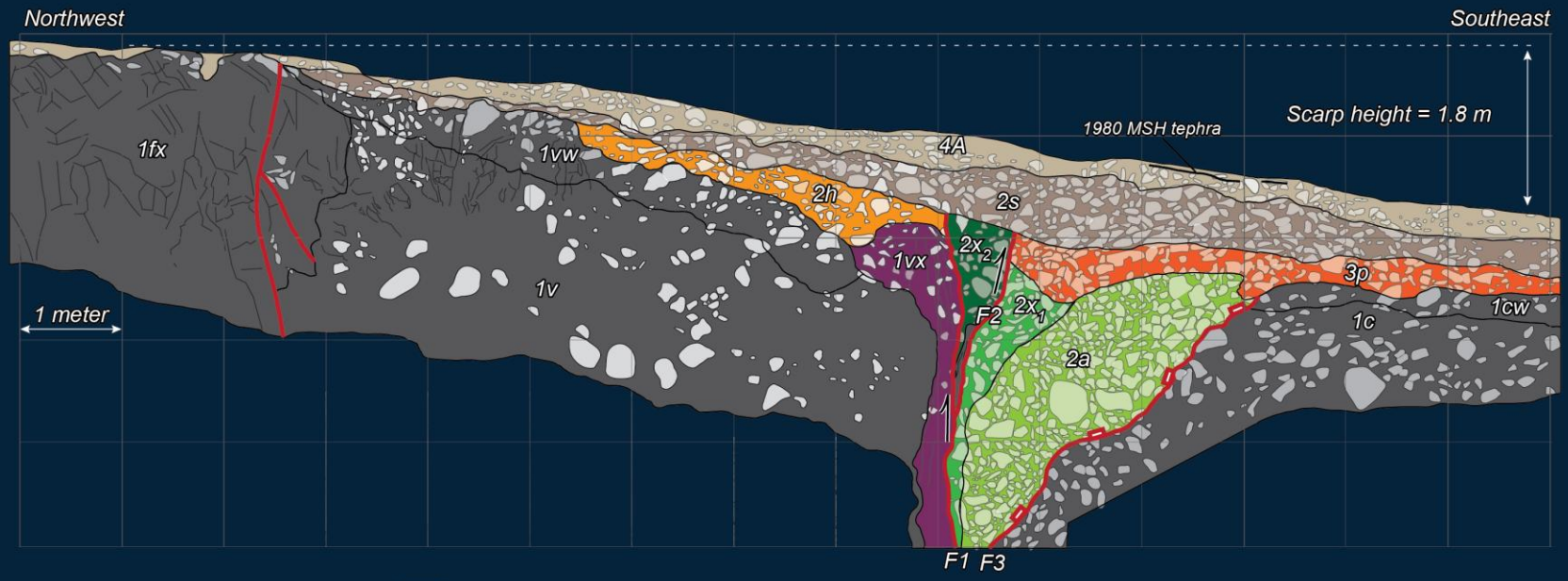
Fault scarp at Boylston Ridge




Ellensburg
Scarp
Ryegrass Pass
and Vantage

Trench at Boylston Mountains

Trench Log, Boylston Mountains Trench



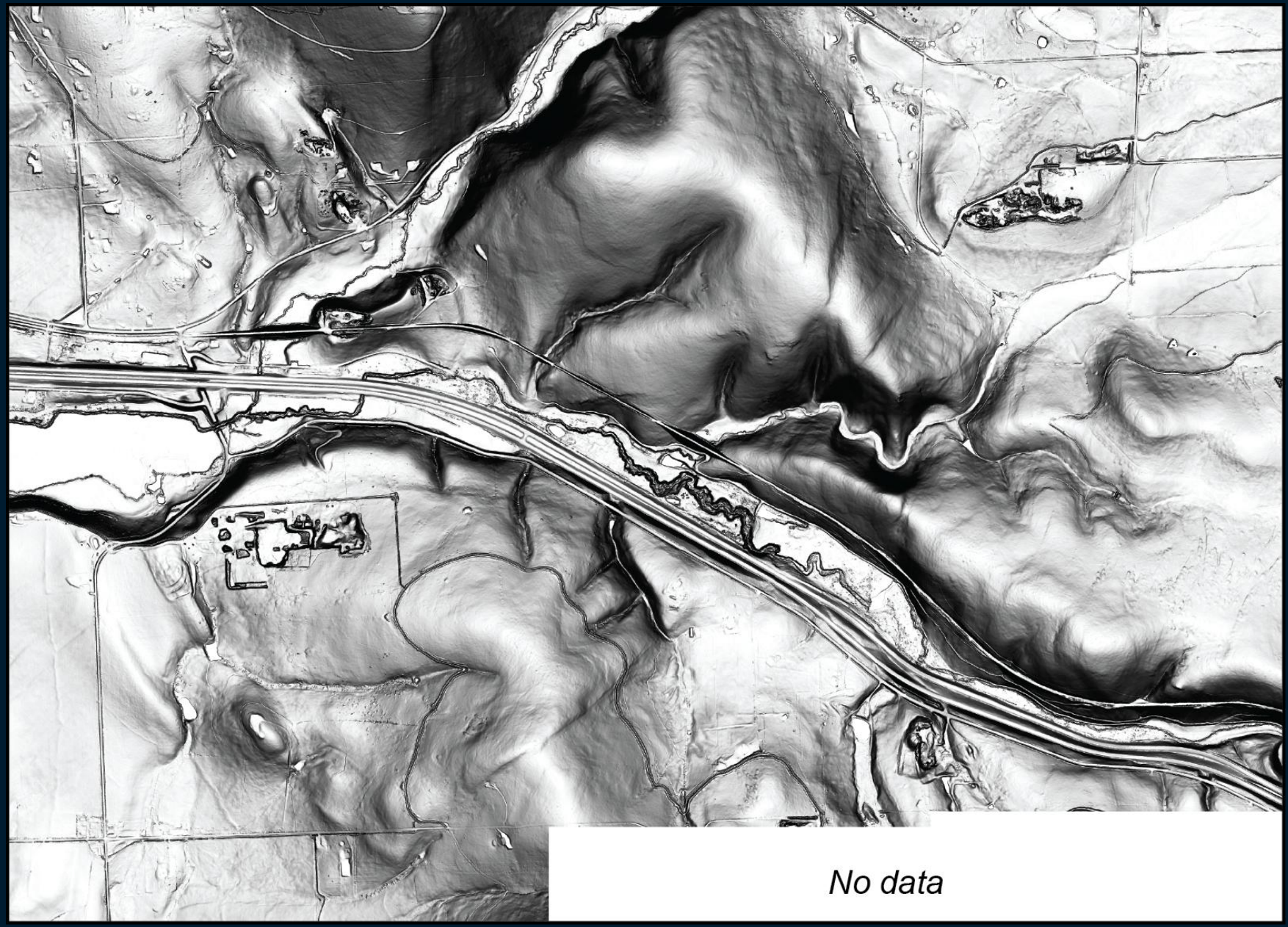
Explanation

- Reverse fault, motion indicated
- Fissure boundary
- Fractures
- Basalt clast/block
- Contact

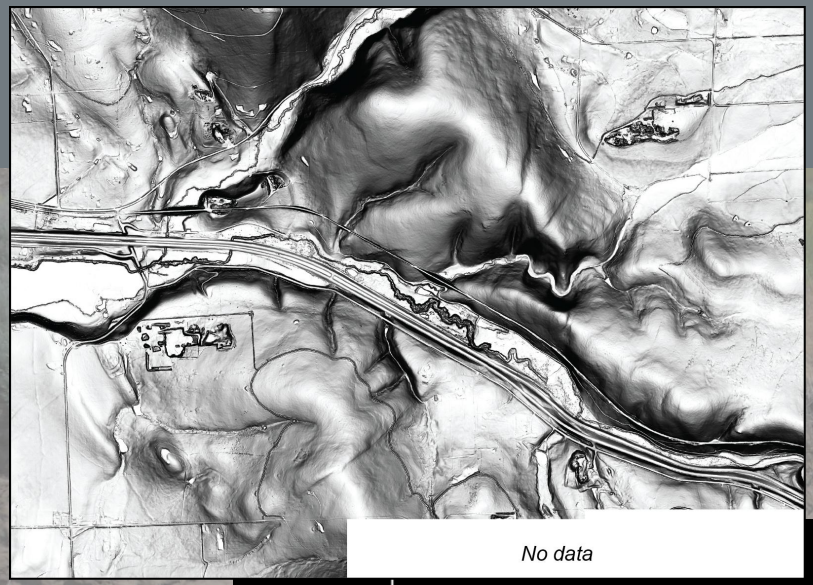
4A	Modern soil
2s	Scarp colluvium, undeformed
2x2	Colluvium from most recent earthquake
3p	Buried soil bearing distictive prismatic structure
2h	Colluvium found only northwest of F1, integrates clasts of 1v and possibly eroded 3p
2x1	Colluvium from earthquake that pre-dates development of 3p
2a	Colluvium from earthquake that pre-dates development of 3p
1cw	Weathered top of 1c, or paleo C-Horizon
1c	Brecciated, blocky, non-vesicular basalt, mapped as Grande Ronde Fm.
1vx	Weathered, fractured 1v adjacent to F1. Fractures are sub- parallel to F1
1vw	Weathered top of 1v, or paleo C-Horizon
1v	Fractured, brecciated, vesicular, blocky basalt, mapped as Grande Ronde Fm.
1fx	Jointed and fractured basalt, possibly colonnade of Grande Ronde Fm.

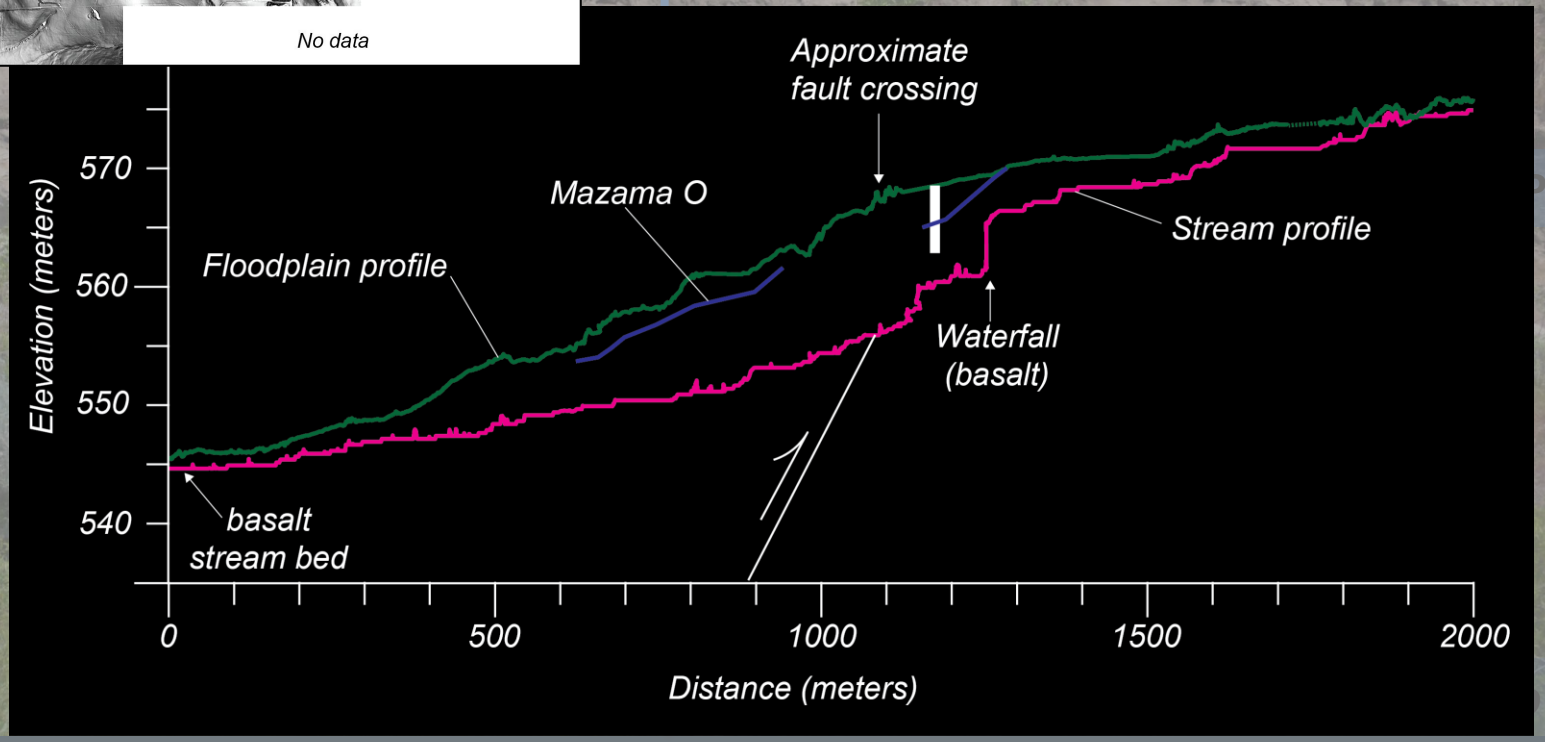
Fault plane dips ~85 degrees NW
Grooves on the fault plane show RL oblique motion on fault

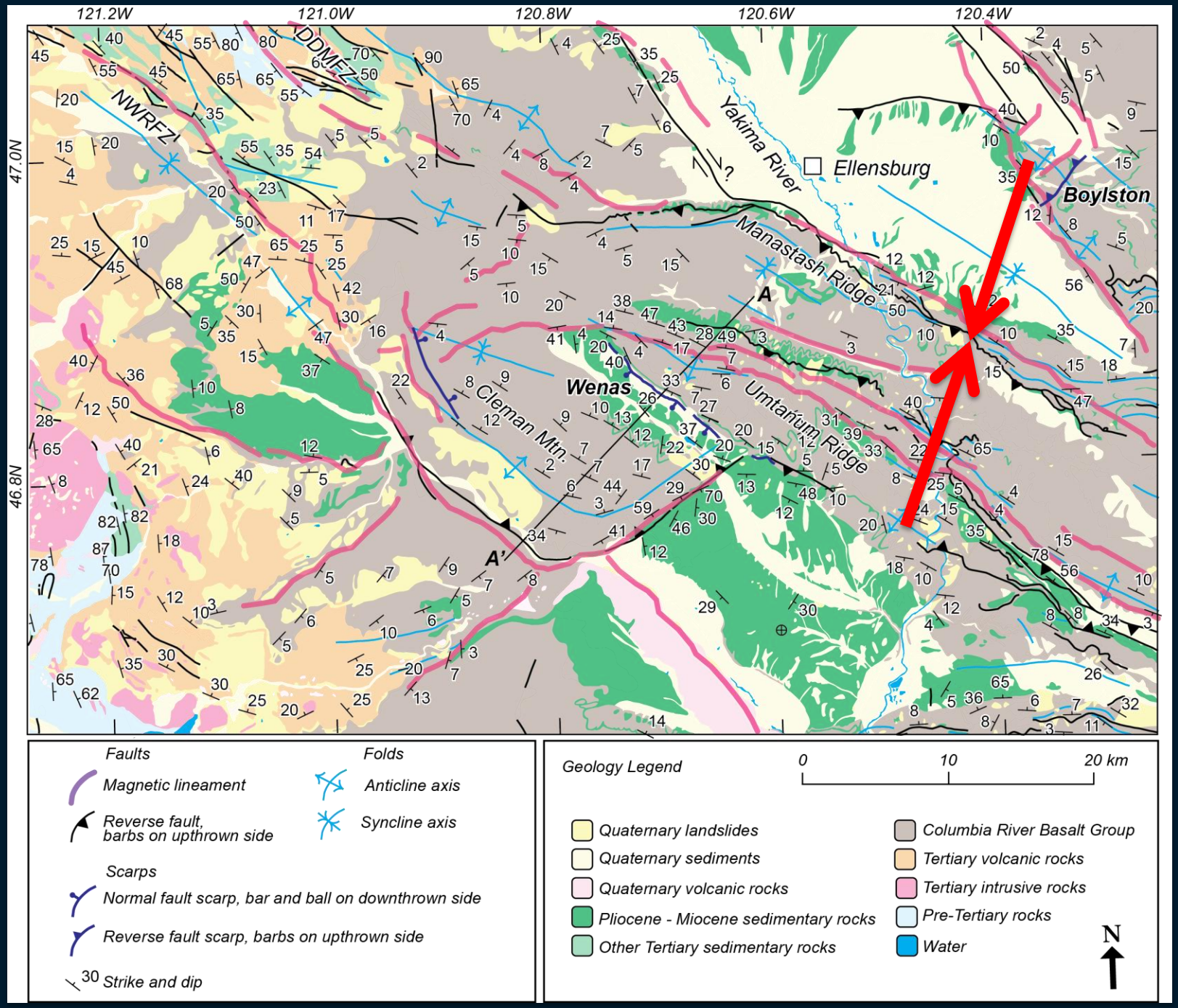
Fault scarp at Boylston Ridge

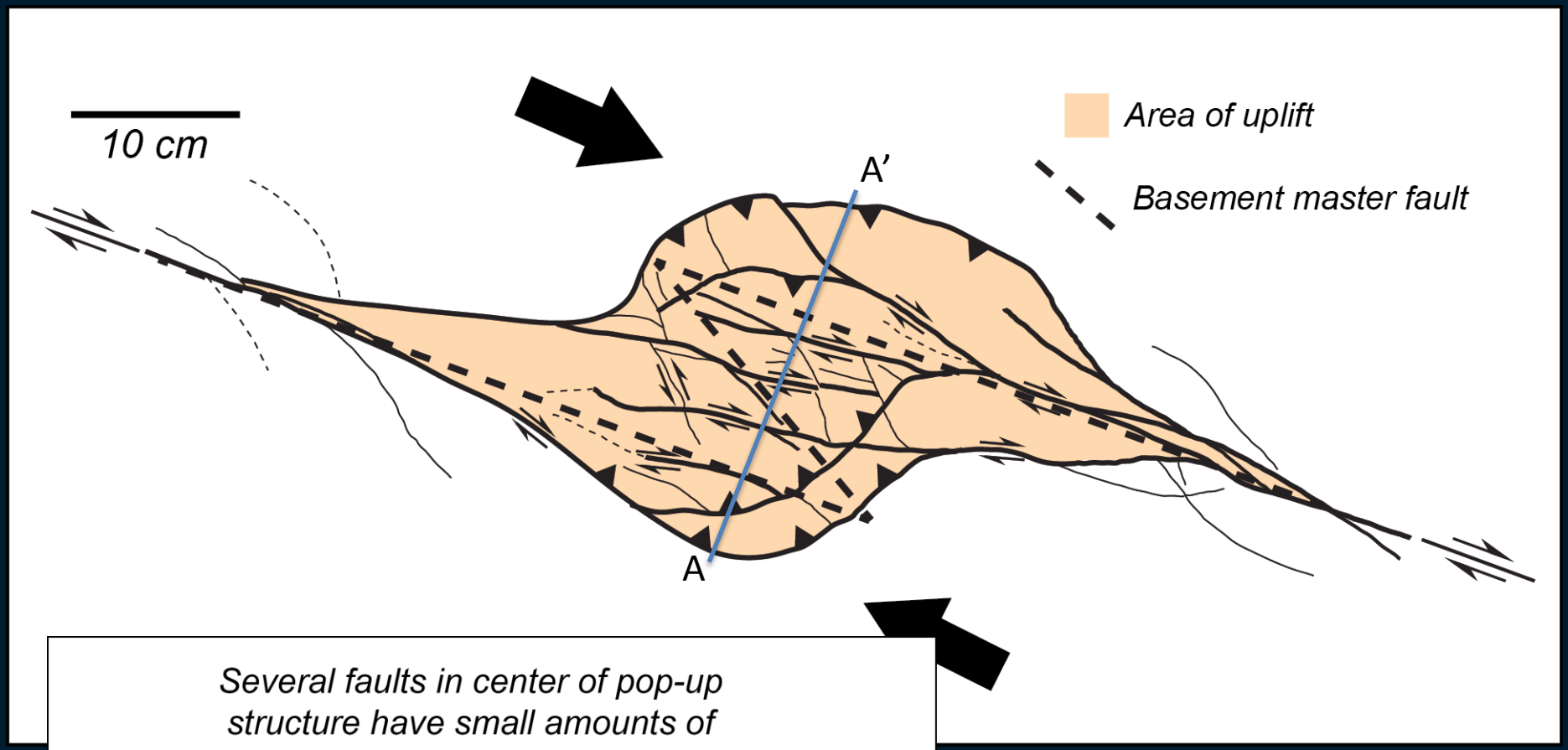


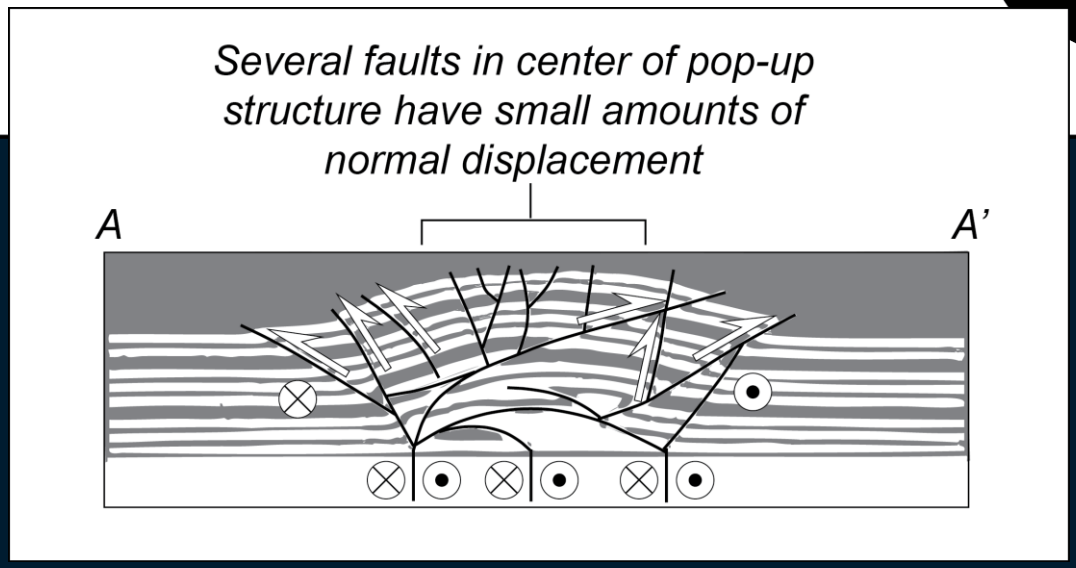
Stratigraphic Section at Fault Crossing in Johnson Canyon





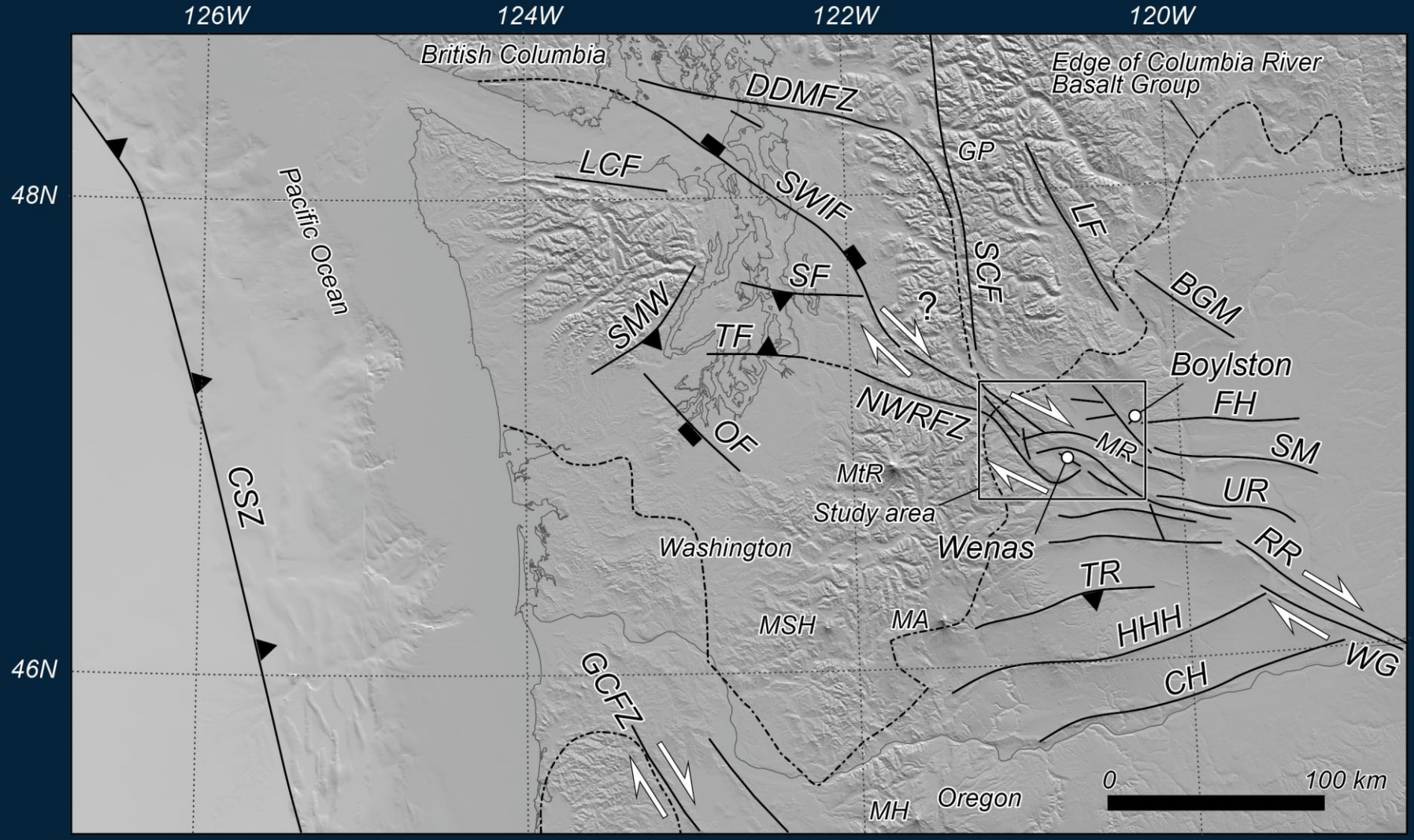

121.2W
121.0W
120.8W
120.6W
120.4W
47.0N
46.8N
DDMFZ
NWRFZ
Yakima River
Ellensburg
Boylston
Manastash Ridge
Umtanum Ridge
Cleman Mtn.
Wenas
A
A'
Faults
Magnetic lineament
Reverse fault, barbs on upthrown side
Folds
Anticline axis
Syncline axis
Scarps
Normal fault scarp, bar and ball on downthrown side
Reverse fault scarp, barbs on upthrown side
30 Strike and dip
Geology Legend
0
10
20 km
Quaternary landslides
Quaternary sediments
Quaternary volcanic rocks
Pliocene - Miocene sedimentary rocks
Other Tertiary sedimentary rocks
Columbia River Basalt Group
Tertiary volcanic rocks
Tertiary intrusive rocks
Pre-Tertiary rocks
Water
N





(McClay and Bonora, AAPG Bulletin, v. 85, no. 2 (February 2001), pp. 233–260)

Regional Interpretation of Trans-arc Fault System



Summary

Air photos and LiDAR reveal scarps at Wenas Valley and Boylston Mountains

Trenching studies along Umtanum Ridge in Wenas Valley show up to five earthquakes in the past ~50 ka on secondary normal faults above a blind (buried) fault tip

Trenching and outcrop studies along the scarp at Boylston Mountains uncovered a steeply dipping reverse fault with evidence for two recent earthquakes (last 7600 yrs)

Pattern of faults and folds is consistent with a popup structure above a RL master fault in pre-CRBG rocks